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Department of Health, Education, and Welfare

Health Care Financing Administration

Adoption of the National Bureau of Standards Fire Safety Evaluation System

DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE

Health Care Financing Administration

Adoption of the National Bureau of Standards Fire Safety Evaluation System for Health Care Facilities

AGENCY: Health Care Financing Administration (HCFA), (HEW).

ACTION: Notice of comment period.

SUMMARY: The Department of Health, Education, and Welfare is proposing to extend use of the new Fire Safety Evaluation System (FSES) to all hospitals participating in the Medicare and Medicaid programs. We are seeking public comment on this proposal and on whether to apply the FSES to intermediate care and skilled nursing facilities.

The Fire Safety Evaluation System (FSES) was designed by the National Bureau of Standards. It defines the combinations of widely accepted fire safety systems and structural arrangements which can be used by health care facilities to meet safety standards equal to or exceeding those in the Life Safety Code.

The FSES provides a framework which guarantees that the high standards of fire safety necessary to protect patients will be met and which is flexible enough to allow for new advances in safety technology and practice. It is based on our experience, which clearly demonstrates that the Life Safety Code can be implemented more effectively and without waste if certain changes are made in the procedures for achieving these mandated levels of safety.

DATES: Consideration will be given to written comments or suggestions received by August 27, 1979.

ADDRESS: Address comments to: Administrator, Health Care Financing Administration, Department of Health, Education, and Welfare, Post Office Box 2372, Washington, D.C. 20013. In commenting, please refer to HSQ–66–N. Organizations and agencies are requested to send comments in duplicate. Comments will be available for public inspection, beginning approximately 2 weeks from today, in room 5231 of the Department's offices at 330 C Street, S.W., Washington, D.C., on Monday through Friday from 8:30 a.m. to 5:00 p.m. (202–245–0950).

FOR FURTHER INFORMATION CONTACT: Patricia Harfst (202) 472–2950.

Supplementary Information:

What the Current Law and Regulations Require

All hospitals, intermediate care facilities and skilled nursing facilities that seek to participate in the Medicare and Medicaid programs (Titles XVIII and XIX of the Social Security Act) must, as a condition of participation, meet the standards of the Life Safety Code of the National Fire Protection Association. Skilled nursing facilities must meet the standards of the 23rd edition (1973) of this code, pursuant to Section 1861(j)(13) of the Social Security Act. Hospitals and intermediate care facilities must meet the standards of the Code's 21st edition (1967), pursuant to 42 CFR 405.1022(b) and 449.12(a)(5).

The Life Safety Code permits the use of alternate means to meet the level of safety that it specifies. Paragraph 1–3118 of the 1973 Code states: "Nothing in this Code is intended to prevent the use of new methods or new devices, providing sufficent technical data is submitted to the authority having jurisdiction to demonstrate that the new method or device is equivalent in quality, strength, fire resistance, effectiveness, durability, and safety to that prescribed by this Code." Although the Life Safety Code allows "equivalent" solutions, it does not define alternative solutions or provide a mechanism for evaluating equivalence. Additionally, Paragraph 1–6111 of the Code states: "The authority having jurisdiction shall determine the adequacy of the exits and other measures for life safety from fire in accordance with the provisions of the Life Safety Code. In cases of practical difficulty or unnecessary hardship, the authority having jurisdiction may grant exception from this Code, but only when it is clearly evident that reasonable safety is thereby secured."

The National Bureau of Standards Fire Safety Evaluation System for Health Care Facilities

In 1974, at the Department's request, the National Bureau of Standards began developing a system for determining how combinations of widely accepted fire safety systems and arrangements could provide a level of safety equivalent to that required in the Life Safety Code. The National Bureau of Standards completed development of its Fire Safety Evaluation System (FSES) for Health Care Facilities in November, 1978. The Department is using the FSES on a limited test basis at this time.

The system provides a model for evaluating the fire risk in a given building, by weighing Code requirements and by incorporating additional factors such as mobility of the patients, age of patients, number of patients per staff member, and number of floors in the building. The FSES also provides a technique for evaluating the various constuction elements of a building and its fire protection features. This allows comparisons between the actual level of fire safety in the building and the level of fire safety that would be provided simply by conformance with individual Code requirements. Equally important, the technique allows for an evaluation of possible alternative approaches available to upgrade an existing facility to a level of fire safety that meets or exceeds the levels prescribed by the Code. The cost effectiveness of alternate fire safety designs is an integral part of this new system.

We are including a more detailed description of the FSES as an appendix to this notice. The detailed description is taken from the publication: *A System for Fire Safety Evaluation of Health Care Facilities* by H. E. Nelson and A. J. Shibe of the National Bureau of Standards. Copies of the complete publication may be obtained by requesting Publication No. NTIS–PB–292273 at $7.50 per copy from: The National Technical Information Service, U.S. Department of Commerce, 5285 Port Royal Road, Springfield, Virginia 22151.

Potential Cost-Benefit Impact of the FSES

The Department believes that the FSES has the potential of enabling facilities to meet those safety standards mandated in the Life Safety Code in a sensible manner and without unnecessary cost or waste. The pilot test of the FSES demonstrates that facilities can meet or exceed the levels of safety prescribed by the Code at about half the cost of meeting each specific requirement of the Code. In 1977, staff at the American Hospital Association estimated that at least $2 billion was necessary for hospitals in this country to meet these requirements. On the basis of preliminary findings, the FSES could save hospitals and hence, the health consumer, $1 billion while maintaining the same mandated levels of safety.

Current Use and Endorsement of the FSES

The National Bureau of Standards consulted with many groups in developing the FSES, including experts in the regulation and specification of fire safety for health care facilities as well as regulatory officials, architects, code-development officials, State fire

protection chiefs, and accrediting officials. Since its publication in November 1978, the FSES has been adopted for use by the Veterans Administration and accepted as an evaluation method by the Joint Commission on the Accreditation of Hospitals. Units of the American Institute of Architects have endorsed the FSES. The Technical Subcommittee on Health Care Occupancies of the National Fire Protection Association recommended that the FSES be adopted as an appendix to the Life Safety Code.

Request for Comments

We are considering extending the use of the FSES to all hospitals participating in the Medicaid and Medicare programs. We request comments, suggestions, and information on this proposal, as well as on the possible application of the FSES to skilled nursing facilities and intermediate care facilities. We particularly seek comments from medical practitioners and groups representing older Americans and consumers.

On December 6, 1978, we published a notice of proposed rulemaking concerning the possible use of sprinkler systems in nursing homes (43 FR 57166). Comments received on this notice will also be given careful consideration as we study the possible application of the FSES to nursing facilities. (Section 1861(j)(13) of the Social Security Act, 42 USC 1395x. Catalog of Federal Domestic Assistance Program No. 13.713, Medical Assistance Programs, and No. 13.773 Medicare—Hospital Insurance Program.)

Approved: June 21, 1979.

Hale Champion,

Acting Secretary.

APPENDIX—A SYSTEM FOR FIRE SAFETY EVALUATION OF HEALTH CARE FACILITIES

H. E. Nelson and A. J. Shibe

Abstract

A quantitative evaluation system for grading health care facilities in terms of fire safety is described. The system can be used to determine how combinations of widely accepted fire safety equipment and building construction features may provide a level of safety equivalent to that required by the widely accepted Life Safety Code of the National Fire Protection Association. The system will provide flexibility to both the designer of new facilities and to the renovator of existing health care facilities.

Three major concepts form the basis for code equivalency:

a. Occupancy Risk—the number of people affected by a given fire, the level of fire they are likely to encounter, and their ability to protect themselves.

b. Building Safety Features—the ability of the building and its fire protection systems to provide measures of safety commensurate with the risk.

c. Safety Redundancy—in-depth protection, through the simultaneous use of alternative safety methodologies such as containment, extinguishment, and people movement methodologies. The design of the complete fire safety system is intended to ensure that the failure of a single protection device or method will not result in a major failure of the entire system.

In this system, equivalency is judged to exist when the total impact of the occupancy risk factors and the compensating building safety features produce a level of safety equal to or greater than that achieved by rigid conformance to the explicit requirements of the NFPA life Safety Code. In this evaluation, safety performance is gauged both in terms of overall safety impact and depth of redundance.

Key words: Risk analysis; fire safety; safety equivalency; health care facilities; Life Safety Code; smoke detection; automatic sprinklers; building construction; interior finishes; building codes; hospitals; nursing homes; Delphi Method; safety evaluation.

1. Introduction

The ideal goal of life/fire safety design is to prevent all fire deaths, injuries and losses under all imaginable circumstances. Practically, however, society can neither forestall all loss of life nor spend limitlessly to avert loss of life due to fire. Building codes are designed to provide a minimum acceptable level of life safety at a cost society is able and willing to support. The Life Safety Code of the National Fire Protection Association (NFPA No. 101) is a voluntary code widely accepted for setting acceptable fire safety levels. The code provides fixed solutions for life safety in designated occupancies, but allows "equivalent" solutions. However, it does not define alternative solutions nor provide a mechanism for evaluating equivalence.

The Center for Fire research with support from the Department of Health, Education and Welfare has developed a system for determining how combinations of widely accepted fire safety systems and arrangements may provide a level of safety equivalent to that required in the 1973 Life Safety Code. The system provides flexibility to the designer of new facilities and to the renovator of existing health care facilities.

The major concepts forming the basis for code-equivalence are:

a. Occupancy Risk—the number of people affected by a given fire, the level of fire they are likely to encounter, and their ability to protect themselves.

b. Building Safety Features—the ability of the building and its fire protection systems to provide measures of safety commensurate with the occupancy risk.

c. Safety Redundancy—in-depth (redundancy) protection, through the simultaneous provision of alternative safety methodologies such as containment, extinguishment, and people movement methodologies. Each methodology provides at least its own independent minimum code level of protection. The design of the complete fire safety system is intended to ensure that the failure of a single protection device or method will not result in a major failure of the entire system.

An adequate life safety system must include a building safety system commensurate with the occupancy risk. The fire Safety Evaluation System provides a model for evaluating the fire risk in a building, by incorporating factors such as mobility of people, number of people at risk, height of building, etc. The calculated risk level provides a minimum target for which levels of protection must be provided by the nature of the building design supplemented by appropriate passive and active fire protection devices.

The evaluation system is also a technique for obtaining a quantitative measure of the level of safety provided by a protected building. This level is determined from an evaluation of the various construction elements and fire protection features. The system measures both the gross level of safety and a set of safety subsystems related to containment, extinguishment and people movement. These subsystems are individually graded to evaluate the depth of redundancey in the building fire safety system. The evaluation system is a mechanism by which the designer can combine a wide variety of fire safety elements into a health care facility plan that provides the level of fire safety required to balance the calculated risk levels.

2. Scope

This evaluation system applies to institutional buildings used for health care purposes involving sleeping facilities for the occupants. In its present form, it was not designed for outpatient clinics or other facilities where all of the occupants are normally awake. The system as presented in this report was also not designed to evaluate penal institutions and has not been proof tested against that type of occupancy.

The system to be described covers all of the aspects of building fire safety currently covered by the Life Safety Code. A few of the items related to built-in utility systems and to operational features and furnishings (fire evacuation plans, fire drills, draperies, etc.) have been excluded from the grading systems. However, these are covered as mandated items in an attachment to the evaluation form. To be considered as having demonstrated equivalent fire safety, it is necessary that the facility satisfy these requirements in addition to the basic fire safety evaluation.

3. Purpose

The purpose of the evaluation system is to provide a technically based mechanism applicable to health care facilities for:

a. Evaluation of an existing health care facility to determine how the actual level of fire safety in that facility compares to the level of fire safety that would be provided by explicit conformance to the requirements of the 1973 Life Safety Code.

b. Evaluation of various alternative approaches available to upgrade an existing facility to a level of fire safety that meets or exceeds the level prescribed by the Life Safety Code.

c. Evaluation of a proposed new facility design to determine how its level of fire safety would compare to that required for such a facility by the Life Safety Code. In this aspect the system can also be used as a design instrument to determine various alternatives that can be considered.

d. Evaluation of the cost effectiveness of alternate fire safety designs and methodologies.

e. Quantitative evaluation of the relative degree of protection involved in a facility or a design feature, as compared with that required by the Life Safety Code.

4. Equivalency Concept

The evaluation system provides a method for determining the design features needed to provide equivalence to the 1973 Life Safety Code. Equivalency for the purpose of the system is judged by comparing the total fire safety level prescribed by the Life Safety Code for health care facilities to the actual safety level in a particular design or an actual facility.

The Life Safety Code represents a consensus view by knowledgeable professionals of the minimum standard for fire safety necessary to safeguard the public interest.

Equivalency determination is based on the concept that, while the Life Safety Code does not include a specific statement of the level of safety provided, it is possible by examination of the Code requirements to establish a base line for comparing the level of safety provided by strict conformance to its requirements with the level of safety provided by alternative systems of safeguards. This comparison can be made on the basis of the total safety performance of the building, including all of its safeguards, without making direct comparisons between a specific Code requirement for an element and the corresponding element as it exists in the building. The concept is suitable for use with any of the recent editions of the NFPA Life Safety Codes for 1967, 1970, 1973 and 1976. The following reference sections are quoted from NFPA 101–1973:

"1–3118. Nothing in this Code is intended to prevent the use of new methods or new devices, providing sufficient technical data is submitted to the authority having jurisdiction to demonstrate that the new method or device is equivalent in quality, strength, fire resistance, effectiveness, durability, and safety to that prescribed by this Code."

"1–4113(c). The specific requirements of this Code for existing buildings may be modified by the authority having jurisdiction to allow alternative arrangements that will secure as nearly equivalent safety to life from fire as practical, but in no case shall the modification be less restrictive or afford less safety to life than compliance with the corresponding provisions contained in this Code for existing buildings. (See also 1–3118)."

Similar paragraphs also exist in the 1967, 1970, and 1976 editions of the Life Safety Code.

Evaluation of equivalency of fire safety is through consideration of three separate concepts. The first is occupancy risk, judged primarily on: how many people are susceptible to a single fire exposure (level of risk), what is their capability to safeguard themselves, and what is the nature of the exposure to which they are being subjected. The second is the capacity of the building and its fire protection systems to provide a safe environment commensurate with the risk. The third is the degree of redundant capabilities to insure the preservation of safety in case of the failure of any one safeguard or method.

5. Project Methodology

Development of the fire safety evaluation system consisted of three operations: system design, professional judgment review and critique, and system testing.

a. System Design. This consisted of: (1) analysis of the stated requirements of the 1973 Life Safety Code versus the fire safety function(s) of each requirement, (2) organization of the results of this analysis into a format suitable for obtaining professional judgments of the comparative worth of the fundamental code requirements relative to the Life Safety Code objectives for health care facilities, (3) development of a computer program to evaluate alternative designs and fire protection systems, and (4) iterative incorporation of system changes resulting from the professional judgment review and system tests.

b. Professional Judgment Review. The professional judgment review was made by two different groups: (1) an NBS group, through the mechanism of a "Delphi" exercise (see appendix A for description of the NBS Delphi operation), and (2) an outside review group (see appendix B). The Delphi group (an ad hoc group of qualified fire protection engineers from the Center for Fire Research, NBS) refined the format, established initial values of the safety parameters, and provided judgment values for selecting individual safety parameters in the redundancy evaluations. The outside consulting group consisted of prominent persons in the field of regulation and specification of fire safety requirements in health care facilities. The group provided broad-based technical and judgmental information for improving both the format and the final values assigned to the safety parameters and the redundancy factors.

c. System Testing. The testing involving a series of exercises to determine the validity of the fire safety evaluation system. These exercises included: field tests of actual facilities by NBS personnel; examinations of many evaluation work sheets completed by health care facilities owners and engineering staff, and by code certification and inspection authorities; and, computer analysis of alternative design systems.

6. Systems Description

6.1 Capabilities and Limitations

The system that has evolved from this effort provides a means of mixing recognized and proven fire safety systems and approaches and evaluating these mixes in terms of the overall fire safety performance of a facility. It permits comparative evaluations of the fire risks and fire safety factors actually present in individual facilities or design. Those features that are in excess of minimum safety requirements are given appropriate credit, reflecting the degree of additional safety actually provided. The credit however is limited in its application to the methodological areas where the safeguards provide credible improvements in safety. Conversely, features that increase one or more aspects of fire risk are appropriately charged for their detrimental impact on safety. The result is intended to be an assessment of total safety performance as compared to a minimum code safety level, which provides opportunity for cost reduction, wider choice of design alternatives, and operational flexibility at greater levels than currently available through explicit compliance with the Life Safety Code.

The most important limitations of the evaluation system are:

a. As presently developed the evaluation system applies only to health care facilities of the types covered under Chapter 10 of the 1973 Life Safety Code.

b. The results are expressed in equivalency to the level of safety achieved by the Life Safety Code, and should not be construed as a measure of total or absolute fire safety.

c. The system, like all existing methods for regulating or evaluating fire safety, is only partially supported by technical information or statistics. The professional judgment of experts in a series of balanced peer-consensus groups is used to bridge the technology gaps.

d. In general the evaluation system is limited to evaluating the interrelationships of those fire safety methodologies and approaches that are defined in the Life Safety Code. There is no basis in the system for accommodating completely innovative approaches (such as automatic venting at the point of fire or the use of halogenated gases as a general protection system) for which equivalency with the Life Safety Code cannot be determined.

e. While the parameter measurements of the system cover built-in structural materials and elements, space arrangement, and fire protection systems and devices, the system does not permit alternate approaches to meeting the Life Safety Code requirements for:

(1) *Utilities* such as heating, air conditioning, electrical, and incinerator systems.

(2) *Furnishings* such as draperies, curtains, wastebaskets, and beds.

(3) *Administrative activities* such as emergency plans and fire drills.

When using the evaluation system, the existing requirements in these three areas are applied in the traditional manner of explicit

conformance with the established standards and requirements as described and/or referenced in the Life Safety Code. A form to accomplish this in terms of ten specific requirements is shown in figure 23 e.

6.2 Logic

The logic of the system is that the level of risk imposed upon persons in a facility must be met by a system of safeguards that provide sufficient safety to protect against that risk, using several interacting but separate design approaches.

The evaluation is made on a *"Fire/Smoke Zone"* basis. This is in recognition of both the history of fires in health care facilities and the traditional arrangements of patient care areas. The evaluation of fire safety is relevant both to the capability of patients surviving fire initiated in such a unit, and to the ability of the unit to exclude the impact of fires external to it. The term "fire/smoke zone" is defined as a space separated from all other spaces by floors, and by horizontal exits or smoke barriers. Where a floor is not subdivided by horizontal exits or smoke barriers, the entire floor is the zone.

The evaluation system applies this logic to each patient use fire/smoke zone through the following steps.

a. Measure *Risk*.

b. Measure overall (General) level of safety.

c. Measure depth (redundancy) of safeguards in terms of:

(1) Fire *Containment* capabilities.

(2) *Extinguishment*, suppression, and control capabilities.

(3) *People Movement* and other occupant protective features.

d. Determine equivalency to the prescribed requirements of the Life Safety Code. Equivalency occurs when the values as measured by this system are such that:

(1) The *General* safety level equals or exceeds the occupancy *Risk* level, and

(2) The *Containment, Extinguishment* and *People Movement* safety levels each independently equals or exceeds the minimum value corresponding to the level of that category required by the Life Safety Code.

6.3 Risk

In establishing a system for evaluating risk, it is recognized that there is a basic level of fire risk inherent in every health care facility. It is also recognized that the amount of furniture, equipment, and supplies (plus the arrangement of these within the space available) depends on the occupant and is not quantified in the safety equivalency measurement. The evaluation system base line for occupancy risk rests on the assumption that the furniture*, equipment, and supplies will be combustible, most adversely located from a fire-safety standpoint, and typical of those normally found in health care facilities.

The factors used to judge the variations in fire risk are given in figure 1. They are applied to individual fire/smoke zones and cover the following risk controlling parameters: the number of patients in the zone, their degree of mobility, their average age, the ratio of patients to attendants, and the height of the zone above street level. These five specific occupancy risk parameters were initially chosen based on the experience and judgment of selected members of the staff of the Fire Safety Engineering Division, Center for Fire Research, and because they are considered to represent the occupancy variables that control the risk in health care facilities. The assessment of the specific parameters and the determination of their relative importance was also based on judgment plus the exercising of the system on test cases to reveal inconsistencies or deviations from accepted safety practice.

The Occupancy Risk Factor for any health care building is the product of five individual risk parameters factors based on the risk factor values shown in figure 1.

The minimum risk conditions have been defined as: a zone containing fewer than five patients, all of whom are of sufficient health to be considered fully mobile and capable of evacuating themselves, their average age being less than 65 and over one; a ratio of patients to attendants of 2:1 or less; and the zone located on the first floor of the building. This condition is assigned an occupancy risk factor of 1.1.

In contrast, the conditions evaluated as representing the upper range of risk as contemplated by the Life Safety Code are based on: more than 30 patients in the zone, all of whom are unable to move without assistance; their average age is over 65 or under one; a ratio of patients to attendants of 10:1 or more; and the zone located above the sixth floor or in the basement. This was assigned an occupancy risk factor of 18. Greater risk values are assigned to patients who cannot be moved and to fire zones which are unstaffed. The maximum possible risk has a factor of 69.

The risk factors were chosen and weighted in descending order of maximum impact as follows:

a. Patient Mobility. The single most important factor controlling risk in a health care facility is the degree to which patients must be assisted in taking actions necessary for their safety. The level of capability in health care facilties will vary from patients who, if informed or directed, will be able to take positive self-protecting actions to those patients who cannot be moved or cannot take the simplest actions to safeguard themselves. In the measurement of occupancy risk factors the least mobile category of patient expected in the zone determines the risk factor for that zone. The rationale for this approach is that if a zone accepts any patient with a reduced mobility status, at any time it may increase the number of those patients. For patients who cannot be moved because of extreme danger of death or serious harm, this condition is considered to be a major risk and a very high risk factor (4.5) is imposed. With this high risk factor, the system requires inclusion of fire safeguards which exceed the normal minimum requirements of the Life Safety Code sufficient to compensate for total lack of movability. This is one of two situations where it is possible for a building, which explicitly complies with the Life Safety Code, to fail to meet the minimum requirements as determined by the evaluation system.

b. Patient Density. The risk factor for occupant density (number of patients within the zone) takes into account both the inherent increase in the maximum fire death potential that occurs as the number of patients in a zone increases, and the problems involved in handling larger numbers of patients during an emergency.

c. Fire/Smoke Zone Location. This risk factor relates to fire department accessibility to the fire. The rating system recognizes the inherent advantage of a first floor zone. It also recognizes the problems of evacuation from higher floors and the virtual impossibility of using external fire fighting efforts above the sixth floor in any building. The risk factor value for zones in basements is the same as for zones at or above the seventh floor.

d. Ratio of Patients to Attendants. This risk factor recognizes the importance to patient safety of attendants immediately available to respond in an emergency. The emergency actions that may be undertaken by the staff include detection, alarm, fire extinguishment, confinement of the fire, establishing barriers between the patients and the fire (e.g. closing patient room doors), rescue, emergency medical aid, and other related functions. A few of these functions, such as detection and alarm, may not be critically related to the ratio of attendants to patients while those functions related to rescue and the closing of patients room doors have a strong relationship to the staffing ratio. The staffing ratio considered is based on the minimum staffing level that would be immediately available (normally night hours). In establishing the risk charges, the charge considered equivalent to the most severe case contemplated under the Life Safety Code was assumed at a patient/attendant ratio of 11 or more, but where there was at least one attendant constantly in or immediately adjacent to and in full observation of the zone. The Life Safety Code is actually silent on this matter and could even be interpreted to permit a situation where there were no attendants in or adjacent to the zone. Such a condition was considered to be a major fire risk and a high risk factor (4.0) is imposed in a situation where patients are left without immediate nursing staff assistance. With this high risk factor, the system requires inclusion of sufficient fire safeguards to reasonably compensate for the lack of human supervision. This is a second situation in which it is possible for a building with fire protection devices to explicitly comply with the Life Safety Code, but to fail to meet the minimum requirements as determined by the evaluation system.

e. Patient Average Age. This risk factor recognizes the increased susceptibility of the elderly and infants up to one year of age to physical harm by smoke particles, gaseous combustion products and heated air. The rating assigns a larger risk factor (1.2) to fire zones occupied by a population whose mode

* Facility furniture could be expected to vary ad hoc so they cannot be considered as known in a system analysis.

is above 65 or below one year. Basically, imposition of this charge will provide additional safety protection in nursing homes for the aged and nurseries.

6.4 Safety Parameters

The general safety factors are measures of those building and fire protection features that bear upon the safety of patients (and other occupants) who may be in the particular fire/smoke zone at the time of a fire.

The safety parameters were selected by examining the specific code element requirements for health care facilities, Chapters 10 and 17 of the 1973 Life Safety Code, and by evaluating the impact of various elements of the Code. The selected safety parameters were modified first by the NBS Delphi panel and later by the consultant groups. The selected safety parameters are shown in figure 2. (See appendix C for an accounting of the inclusion of code elements in the evaluation system.)

Each of the safety parameters was analyzed. Where the current Code requirements recognize several different levels of a parameter (e.g. the Life Safety Code recognizes eight different types of construction), the most important alternatives were listed. In addition, conditions likely to be encountered in situations failing to meet the explicit Code requirements, and conditions exceeding those required by the Code but available for increased protection were also listed. Figure 3 shows the final "matrix" form of the breakdown of the 13 selected safety parameters, each having three to seven subdivisions.

The safety parameters are designed to constitute a complete assembly of all of the basic building factors determining the level of safety in a health care facility for which equivalency could be expressed. In addition, we collected and attached to the inspection form an additional series of items required by the Life Safety Code but outside the scope of the equivalency covered by the listed safety parameters. These relate primarily to building utilities, operational features and furnishings and they are listed in part e of figure 23.

6.5 Safety Parameter Valuation

In order to provide a method of bringing the best available consensus judgment and experience together to judge the relative impact on general safety of each of the parameters in each of the potential conditions listed, a Delphi type peer group was established. This peer group consisted of members of the Fire Safety Engineering Division, Center for Fire Research, NBS, with the greatest background and experience in the application of fire protection engineering principles and practices to buildings. The membership and basis for the Delphi approach are covered in appendix A.

Each member of the group was provided with copies of the initial matrix similar to the one shown in figure 3, but without numerical parameter values. Each person then evaluated the relative importance of each item in the entire matrix of parameters without consultation with other members of the group. The members of the Delphi group were advised that the risk being considered covered new and existing health care facilities and that the objective was a system to measure equivalency with the 1973 Life Safety Code. The value judgments made by this group are, therefore, considered to be based on the character and needs of patients in health care facilities and the current approach to these embodied in the Life Safety Code. In addition, each member of the group evaluated separately the same matrix in relation to the redundant subsystems which are discussed in section 7.7. In executing the matrix each peer group member was requested to assign a value of +10 to that safety parameter element (or level) considered to be the single most important to safety to life and to compare all other elements in the matrix to that base. A zero value represented a neutral condition; i.e. a safety parameter at this level would not increase or decrease the safety conditions of a fire zone. Negative values represented deficiencies; i.e. safety parameters at this level decreased the safety conditions of a fire/smoke zone.

After an initial analysis of the results, the peer group was asked to meet in conference on several occasions. The peer group on those occasions deviated from the traditional Delphi approach but instead reviewed differences and concepts, with a view to achieving consensus agreement on categories and on selection of the numerical values.

Several categories were modified and qualified. A significant adjustment was to shift the numbers so that a base line would be established in which negative charges would not be made against any general safety parameter that was in explicit conformity with the requirements of the 1973 Life Safety Code.

6.6 Relating Safety Parameter Values to Life Safety Code Requirements

The relationship between the safety parameter values and the code requirements was established by summing the value of all of the credits and deficits of the safety parameter elements for a health care facility that exactly met all of the requirements prescribed by the 1973 Life Safety Code. Attempts to do this disclosed that the Life Safety Code actually had eleven sets of requirements, seven for sprinklered facilities and four non-sprinklered facilities (see figures 4 through 18). Based on the relative value of protection methodologies developed by the Delphi group and refined by the review processes described later in this report, the levels of safety prescribed by these requirements are:

	General safety value required	
	Nonsprinklered buildings	Sprinklered buildings
1. New buildings 1-story in height	13	16
2. New buildings over 1-story in height	18	[a] 23
3. Existing buildings 1-story in height	5	8
4. Existing buildings over 1-story in height	9	[b] 16

[a] 20 for 2- or 3-story buildings.
[b] 14 for 3-story and 10 for 2-story buildings.

These values represent the level of general safety required by the 1973 Life Safety Code to house health care occupants in the class and height of building indicated. The analysis demonstrates that, in terms of the values in the evaluation system, the Life Safety Code minimum requirements are those for non-sprinklered buildings. The highest total value developed for a non-sprinklered building is 18. The importance of this value is that it was used as the approximate base line for the establishment of measurement of risk in a multi-story building and is the principal balance point for comparing occupancy risk with general safety. Thirteen is the comparable value for a single story building.

The values for existing buildings demonstrate the reduced level of general safety accepted by the Life Safety Code for these buildings. For a one-story building the general safety value is +13 for a new building and +5 for an existing building, indicating that for an existing one-story building only 38% of the score expected a new one-story building is required. Similarly, the ratio of existing multi-story buildings to that for new multi-story buildings is ½. The 0.5 factor in table 3B of the Fire/Smoke Zone Evaluation Work Sheet reflects this ratio.

6.7 Redundant Safety Subsystems

A basic principal of the Life Safety Code is that there will be a redundancy of protection so that the failure of a single protection device or method will not result in a major failure of the entire safety system. In addition, the development of a redundant approach, as used in this safety evaluation system, avoids the pitfall of traditional approaches to developing grading systems where all of the elements are considered mutually eclusive of each other and a single total score determines acceptability. Under such a system, it is possible to completely disguise the absence of a critical element. The evaluation system establishes redundancy on the basis of in-depth coverage of the principal fire safety methodologies. The redundant methodologies used in the system are those related to fire safety through containment, through extinguishment and through people movement (including refuge).

The redundant methodologies were chosen after examination of decision tree approaches [1,2].[1] These divide fire protection by element. Four different methodologies of managing fire impact were identified. These are control of the fuel and arrangement; compartmentation and other mechanisms of containment of the fire and its impact; extinguishment suppression and other means of terminating fire development; and the provision of safe locations of refuge either by

[1] Numbers in brackets refer to the references at the end of the paper.

evacuation or by establishment of safe areas of refuge. Those elements related to the control of fuel and its arrangement are incorporated into the risk analysis portion, in terms of the occupancy risk base line. Therefore, only three redundant methodologies were used in the analysis.

As part of the initial Delphi exercise, each member of the Delphi group completed a matrix establishing his judgment on the relative importance of the items in the general safety parameter matrix; he also made additional judgments on the same matrix elements related to the separate fire safety methodologies of containment, extinguishment, and people movement. These were then processed and analyzed and reviewed in subsequent conference meetings of the Delphi group. By this process, the parameters that have a significant impact on each of the redundant methodologies were identified. Many of the parametes impact on more than one of the methodlogies. In the jdugment of the group only sprinkler protection impacts on all three. Figure 19 shows the breakdown in terms of which parameters apply to which methodologies.

Each of these subsystems was then evaluated to determine the point value that would result from explicit compliance with the requirements of the Life Safety Code for that subsystem. Because of the variance between new and existing buildings and between single story and multi-story-type buildings, four values were determined foreach of the redundant safety methodologies. Figures 20, 21, and 22 demonstrate how these values were established.

In this fire safety evaluation system these values are mandatory minimum values that must be met regardless of the overall evaluated level of occupany risk or the overall evaluated level of general safety.

6.8 Overall Safety Evaluation of a Fire/Smoke Zone

This evaluation system determines the efficacy of any arrangement of the listed fire safety subsystem elements in a fire/smoke zone by considering the risk factors and safety parameters relative to the level of safety that would be achieved by explicit conformance with the specific requirement of the Life Safety Code (NFPA 101–1973). In order to be determined as equivalent the measurement must demonstrate that:

1. The general safety level produces a value that equals or exceeds the determined value or charge for risk.

2. Each of the three individual redundancy groupings (containment safety; extinguishment safety; and people movement safety) must have an arrangement of safeguards that meet the prescribed minimum for that redundant grouping independent of the other condition.

7. Fire/Smoke Zone Evaluation Work Sheet for Health Care Facilities

All of the parameters, variables and formulas for determining the facility safety equivalency with the Life Safety Code are contained in a self-instruction form. A separate manual (appendix D) has been prepared to assist in completion of the evaluation form. The manual provides expanded discussions and definitions of various items in the evaluation sheet to assist the surveyor or reviewer when questions of definitions, interpretations, or meanings arise. To evaluate totally a health care facility, it is necessary to evaluate each of the different fire/smoke zones. A zone is any space which is separated from all other spaces by floors, horizontal exits, or smoke barriers. Where a floor is not subdivided by smoke barriers, the entire floor is the zone. See figure 23 for an example of the form and appendix E for examples of a completed form.

8. Computer Analysis

The evaluation system has a theoretical capability of evaluating about 230 million combinations of the 13 safety parameters and variations. Practical arrangements in existing buildings and future design are of the order of a few thousand. For the purpose of verifying the original proposed system as well as to analyze potential proposed changes, a computer program was developed. The program generates all arrangements that are valid, based on data given for the safety parameters. Using the Fire Safety Evaluation Work Sheet an experienced engineer or facility can manually analyze 10 to 15 differently organized zones, and establish the most suitable configuration for the facility. By using the computer program the evaluator is able to review all possible solutions to his problem, and he can also be assured that answers are not biased by individual preference. The printouts of the zone arrangements can be easily analyzed by an experienced individual to establish equivalency of solutions. Appendix F provides additional detail on this program.

9. Evaluation System Analysis

An effort has been made to make the system consistent with accepted and sound fire protection engineering practice and theory. While the most advanced scientific knowledge has been used in developing the system, the state-of-the-art requires that the insight and professional judgment of experts in the field serve as the base for information in developing the system, and the available technical knowledge (including results of fire tests, statistical analyses, fire investigations, etc.) serves a supportive role. In the development of the fire safety evaluation system, therefore, both the NBS Delphi group and the professional consulting panel described in sections 9.1 and 9.2 below were selected on the basis of expertise and interest.

In the systems proofing effort the capacity of these panels was broadened by using a two-step judgment approach. In the first step the relative worth of each parameter was individually judged on its relationship to other parameters. This evaluation was made in terms of each parameter's contribution to both general safety and to each of the redundant safety requirements. In the second phase the parameter values, developed in the preceding phase, were applied to a large number of test cases, scenarios and reviews of specific facilities. The resulting fire safety system configurations were then judged on overall equivalency to configurations prescribed by the 1973 Life Safety Code. This process provided a balance and cross check between judgments of the value of the individual parameters and evaluations of the overall product.

9.1 NBS Delphi Group

The initial safety parameter values (figure 3) were established by the NBS Delphi group. The group was composed of qualified fire protection engineers in the Fire Safety Engineering Division (see figure 24). The group was also used at different development stages to clarify technical problems and to analyze proposed changes suggested by the outside consultants, HEW or others.

Delphi is a procedure for obtaining the most reliable consensus of opinion of a group recognized as experts on a technical question for which no "true" answer is within the state of current knowledge [3]. The essence of the process is that the question is considered independently by members of the group. The response is tabulated and circulated to group members who revise their "answers" on the basis of further thought and consideration of the aggregate response. Additional rounds of response invplving direct contact and discussion among the group members can ensue. The number of interactions is usually limited to four. In its classic form Delphi incorporates various statistical measures of the "convergence" to consensus, which are circulated within the group along with the responses. The Delphi exercise at NBS was in a form known as Policy Delphi. In this variant the statistical measures to establish convergence consensus are foregone and the "referee" or manager of the process takes a fairly active role in the discussion among the group members. In any of its formats, Delphi is widely perceived as furnishing useful information in areas in which questions are difficult to pose precisely, let alone answer definitely. A more detailed discussion of the Delphi operation is given in appendix A.

9.2 Consultant Group

After the NBS Delphi group agreed on an initial set of parameters and their values, the system was presented to the consultant group.

The group consisted of prominent persons in the regulation or specification of fire safety for health care facilities. It included regulatory officials, code writing officials, government agency fire protection chiefs, and accrediting officials representing a cross section of the applied field. The membership and dates of meetings are shown in appendix B. This consultant group contributed to the development of the system and met in four separate sessions. In those meetings the consultants operated as a committee of the whole, reviewing the concept and individually discussing and evaluating the parameter values as developed by the NBS peer group. Important revisions resulted. Many of these revisions were in the form of restraints placed on the degree of liberality in the safety parameter values so as to require a more conservative and supportable approach.

9.3 Inter-Group Relationships

Throughout the project the project staff maintained liaison and a flow through the described review groups and a recently established task group of the National Fire Protection Association Committee on Safety to Life. This task group is studying the evaluation system for possible inclusion in the NFPA Life Safety Code. Figure 24 outlines this flow.

10. Summary

The conclusions resulting from this study are briefly stated as follows:

a. A methodology has been developed and described for generating equivalency to a specified set of occupancy safety requirements. It is based on the understanding of level of occupancy risk, building safety and redundancy of safeguards. This methodology can provide the necessary flexibility for a designer to achieve minimum cost solutions for a specified level of safety.

b. The described methodology "System for Fire Safety Evaluation of Health Care Facilities," is a specific example of an equivalency approach. The system provides equivalency to the minimum life requirements for the health care facility as prescribed by Life Safety Code 101–1973. The system can be updated for later Life Safety Code editions for health care facilities.

c. Other equivalency systems can be developed for other occupancies but this will require detailed analysis of the risk level, the variety of building safety requirements, the necessary redundance equations, and other aspects of the specific occupancy involved.

11. References

[1] National Fire Protection Association, "Decision Tree," NFPA, Boston, 1974.

[2] Watts, J., "The Goal Oriented Systems Approach," NBS–GCR–77–103, National Bureau of Standards, Washington, D.C., July 12, 1977.

[3] Dalley, N. and Helmer, D., "An Experimental Application of the Delphi Method to the Use of Experts," Management Science 9, No. 3, p. 458 (April 1963).

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